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Ochi

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(54) **PNEUMATIC TIRE**

(75) Inventor: **Naoya Ochi**, Higashimurayama (JP)

(73) Assignee: **BRIDGESTONE CORPORATION**, Tokyo (JP)

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B60C 11/04 (2006.01)

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USPC 152/209.1, 209.3, 209.12, 209.18, 152/209.25, 209.26, 209.27
See application file for complete search history.

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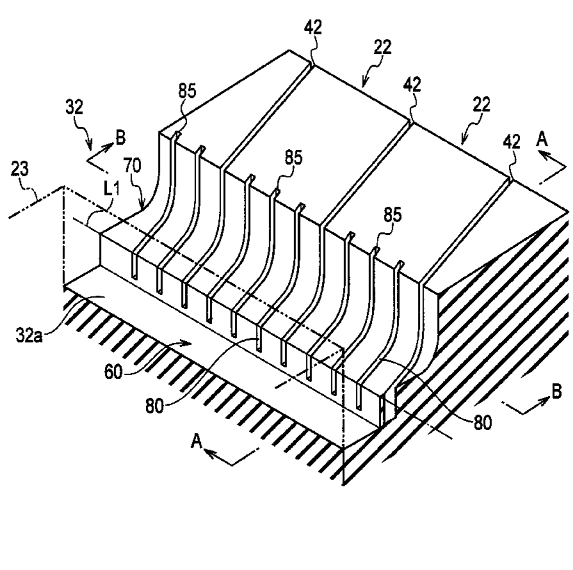
Primary Examiner — Seyed Masoud Malekzadeh
(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

(57) **ABSTRACT**

In a present invention, in a pneumatic tire **1**A, a circumferential groove **32** extending in a tire circumferential direction is formed by land portions **20** constituting a tread surface **10** coming into contact with a road surface. A flat groove portion **60** and an in-groove land portion **70** are formed in the circumferential groove **32**. The flat groove portion **60** is a flat surface of a groove bottom **32***a* of the circumferential groove **32**. The in-groove land portion **70** is raised toward the tread surface **10** side from the groove bottom **32***a* of the circumferential groove **32**. Multiple narrow grooves **80** extending in a tread width direction are formed in the in-groove land portion **70**. A wide-groove width W**1** of the circumferential groove **32** in the tread width direction is 5 to 30% of a tread width TW of the tread surface in the tread width direction.

11 Claims, 7 Drawing Sheets



(52) **U.S. Cl.**
CPC ***B60C11/0309*** (2013.04); ***B60C 11/042*** (2013.04); *B60C 2011/0381* (2013.04); *B60C 2011/0388* (2013.04); *B60C 2011/1209* (2013.04); *B60C 2011/133* (2013.04); *B60C 2011/1338* (2013.04); *B60C 2011/1361* (2013.04)

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FIG. 1

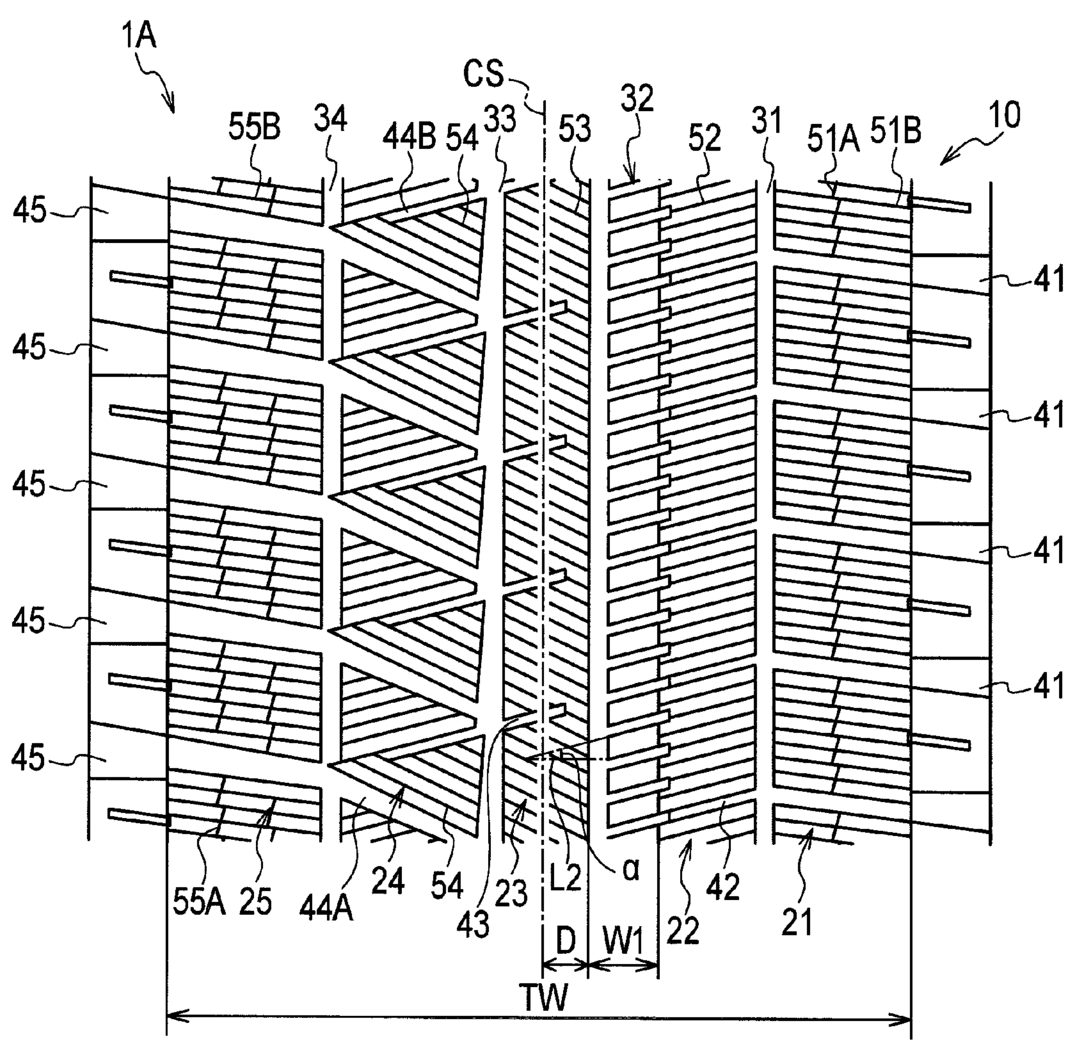

1A
CS
32
10
55B
34
44B
54
33
53
52
31
51A
51B
45
41
55A
25
44A
24
54
43
23
L2
α
22
42
21
D
W1
TW

FIG. 2

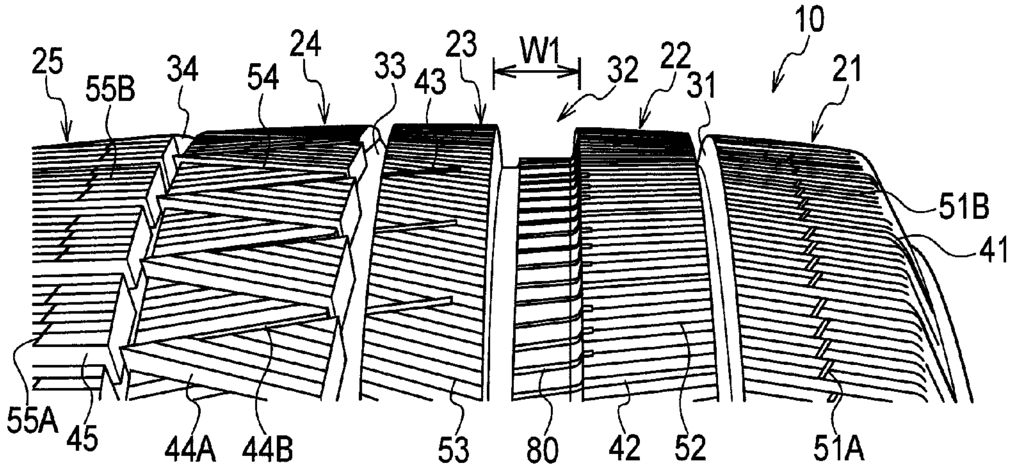
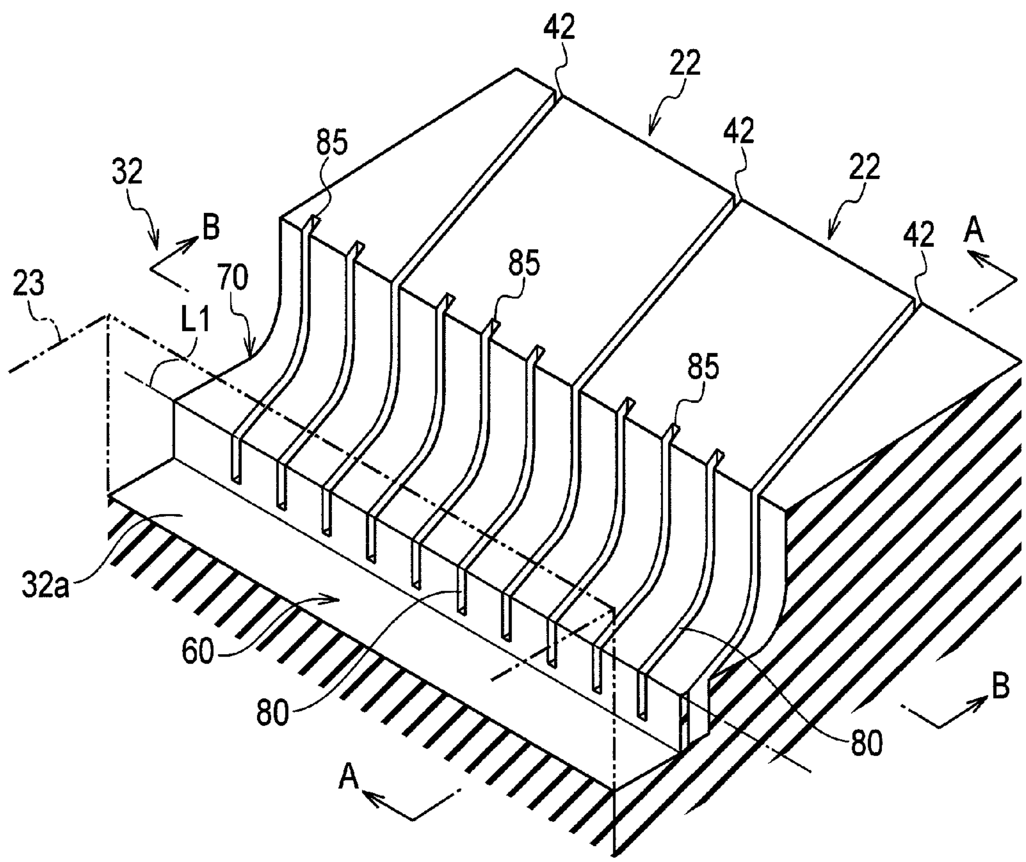

25
55B
34
54
24
33
43
23
W1
32
22
31
10
21
51B
41
55A
45
44A
44B
53
80
42
52
51A

FIG. 3


42
22
42
22
85
32
B
70
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42
A
23
L1
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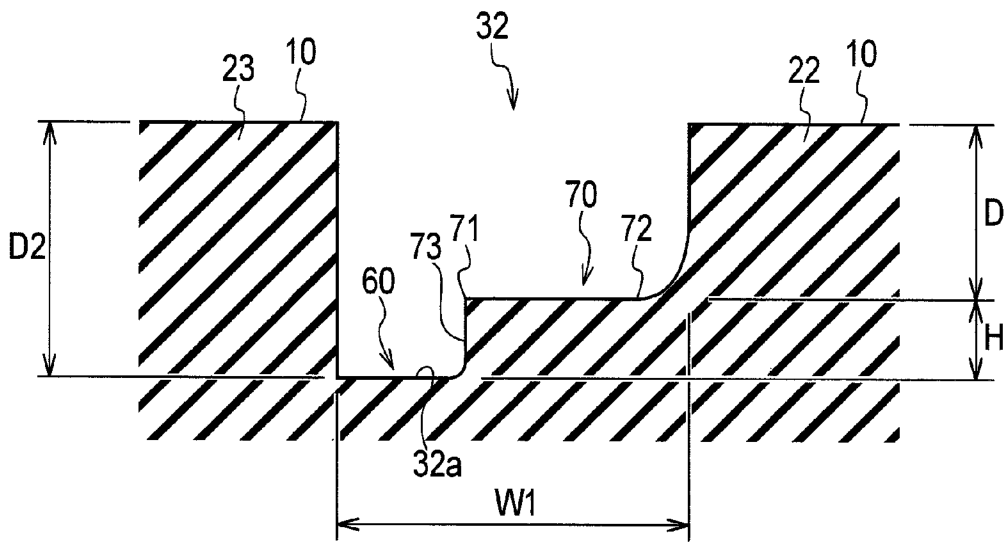
32a
60
80
B
80
A

FIG. 4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23
10
22
10
D2
D1
70
73
71
72
60
H
32a
W1

FIG. 5

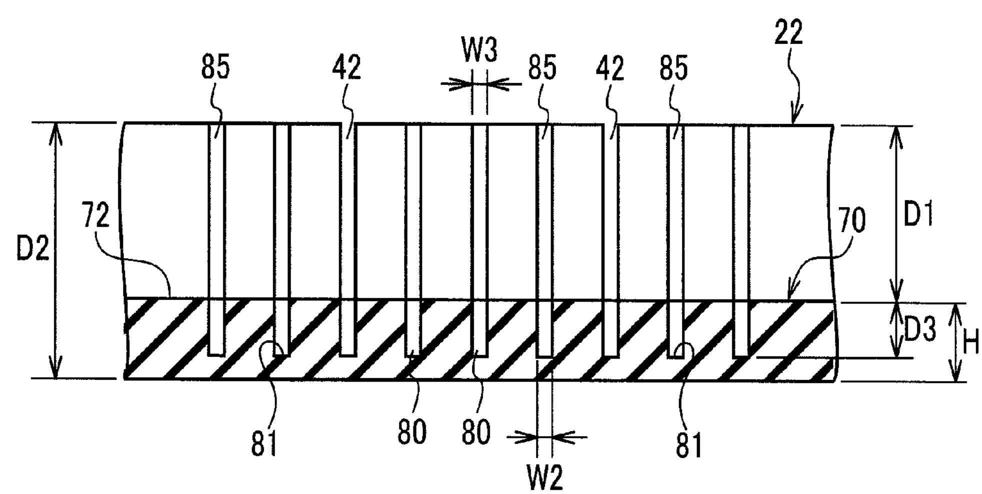
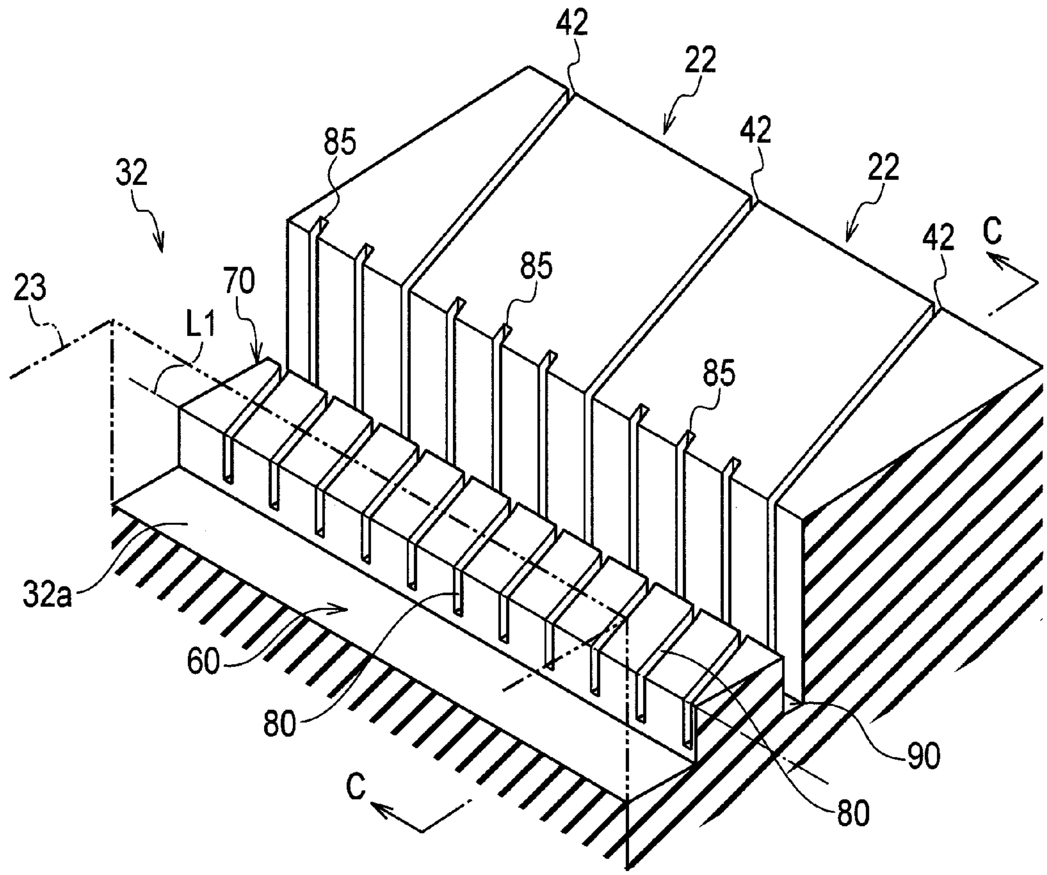

22
85
42
W3
85
42
85
D2
72
70
D1
D3
H
81
80
80
W2
81

FIG. 6


42
22
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22
42
C
85
32
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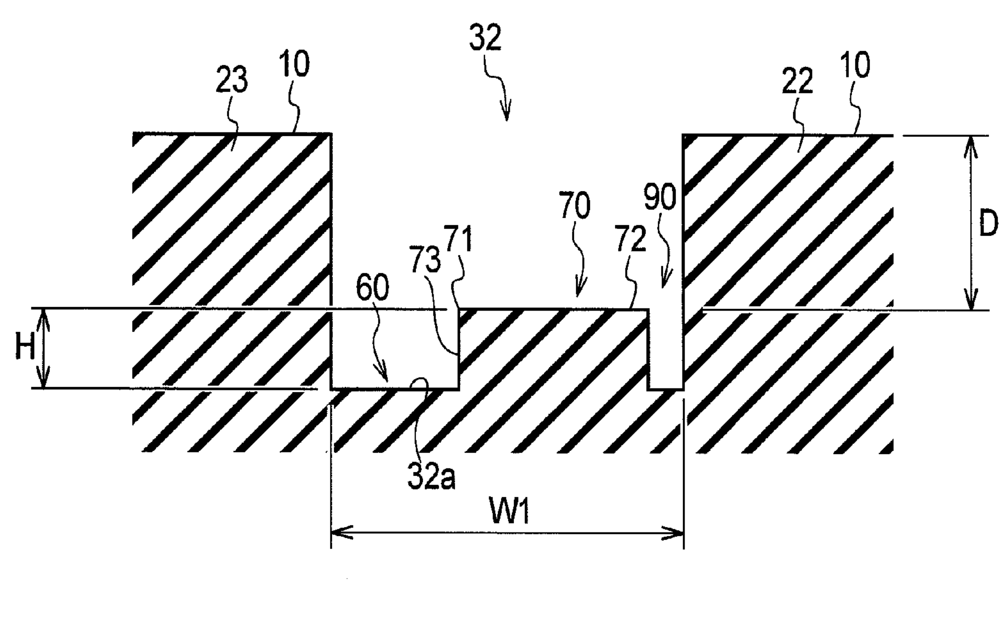
23
L1
70
32a
60
80
90
80
C

FIG. 7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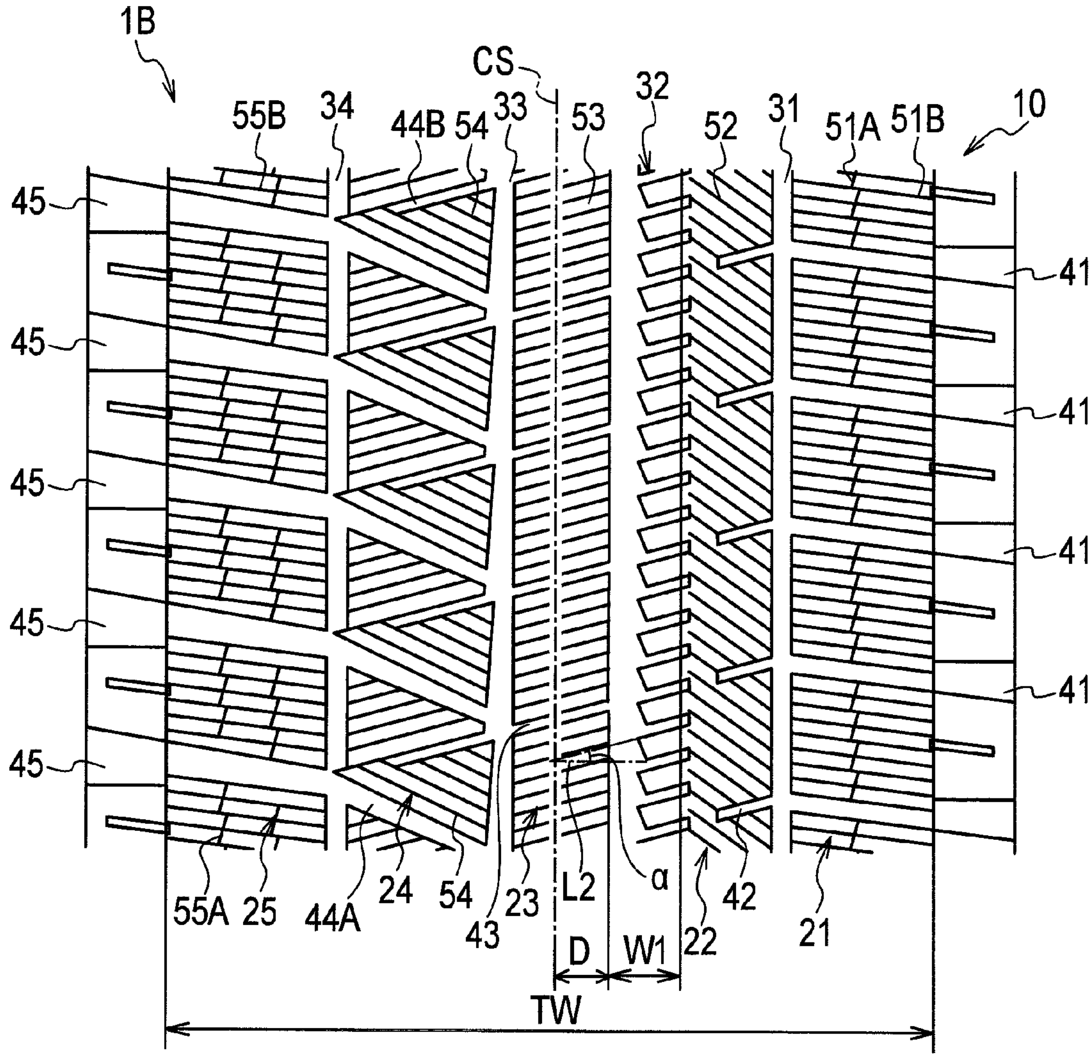
72
60
H
32a
W1

FIG. 8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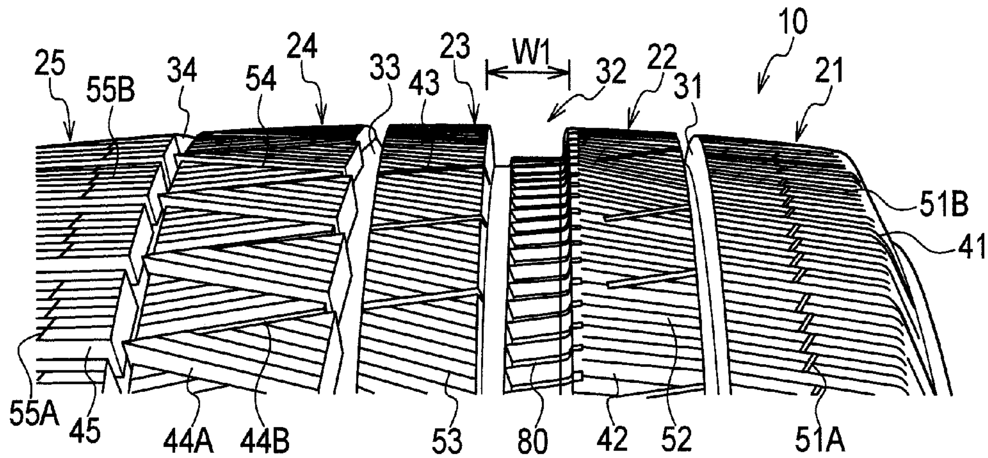
41
41
41
41
41
55A
25
44A
24
54
43
23
L2
α
22
42
21
D
W1
TW

FIG. 9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W1
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55A
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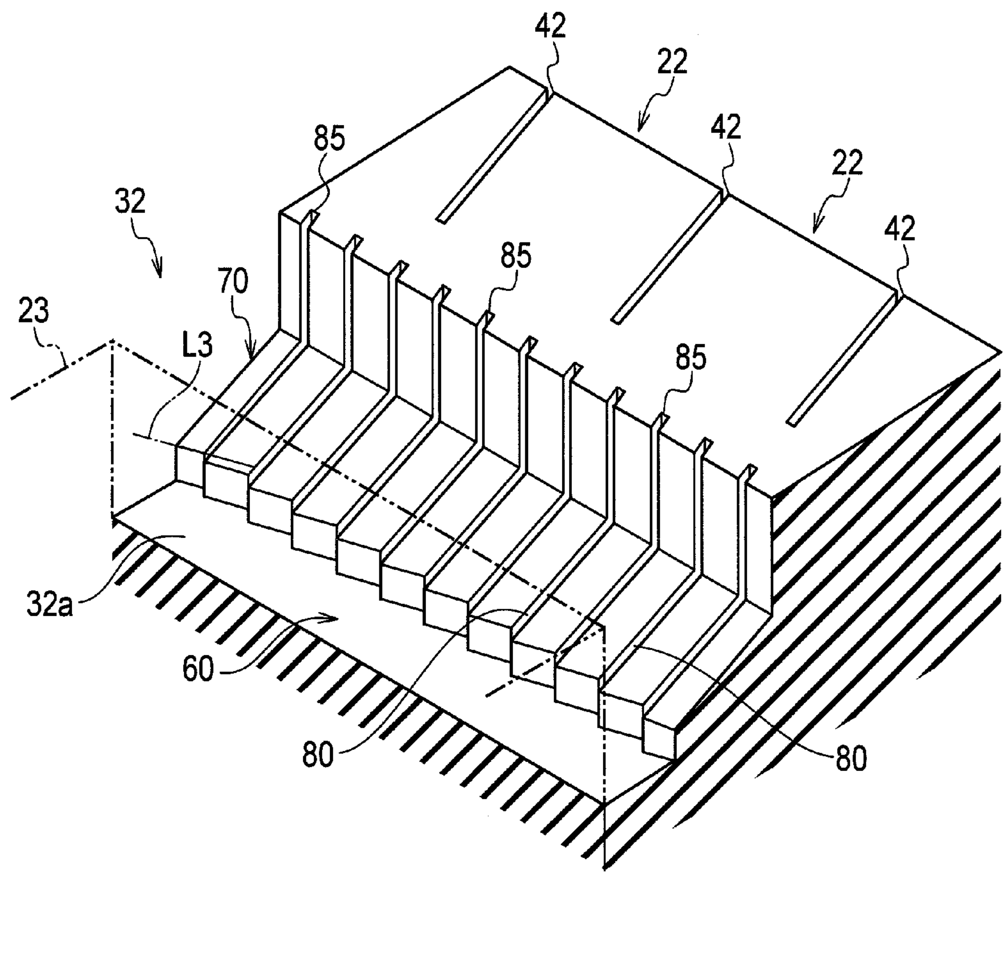
44A
44B
53
80
42
52
51A

FIG. 10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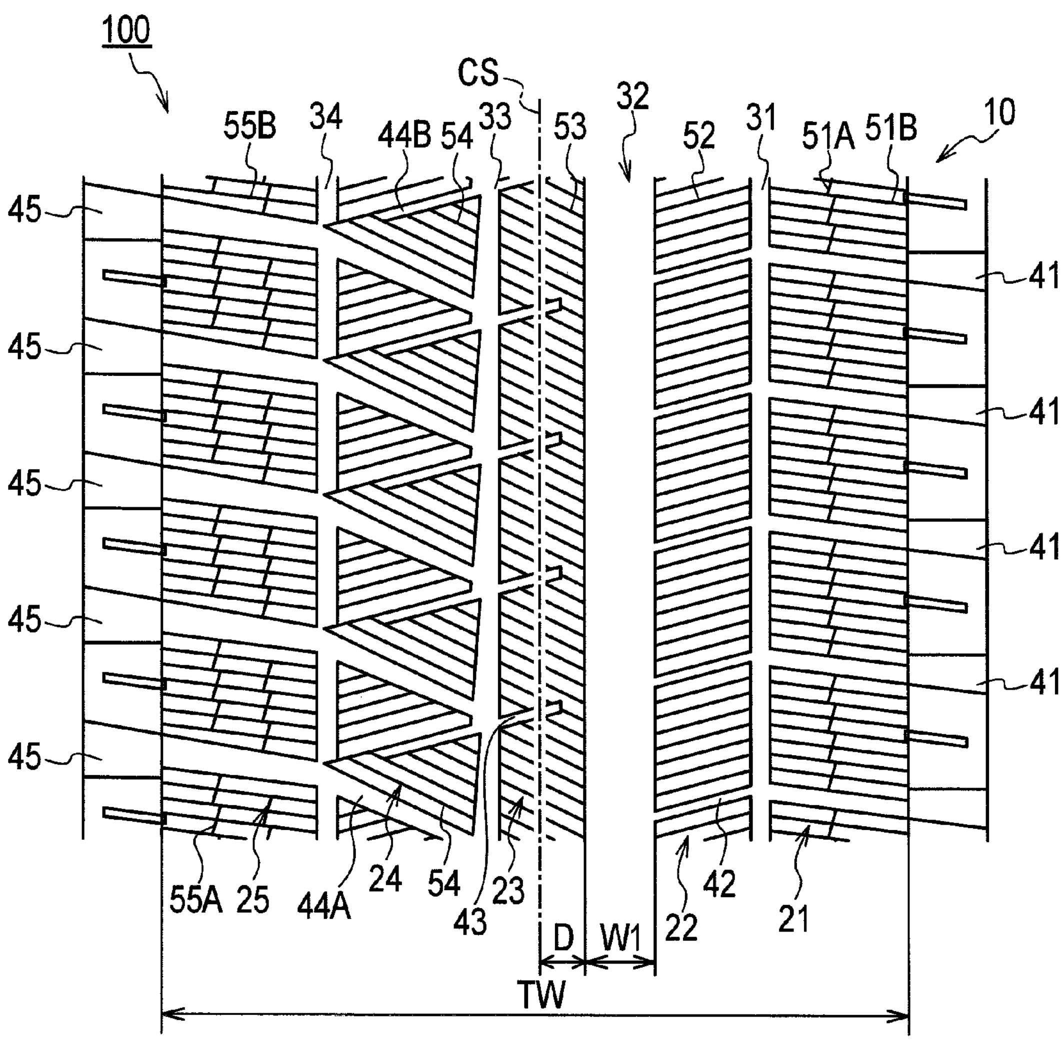
L3
32a
60
80
80

FIG. 11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44B
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31
51A
51B
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45
45
45
45
45
45
41
41
41
41
41
55A
25
44A
24
54
43
23
D
W1
22
42
21
TW

PNEUMATIC TIRE

TECHNICAL FIELD

The present invention relates to a pneumatic tire in which circumferential grooves extending in a tire circumferential direction are formed, and particularly to a pneumatic tire designed for icy and snowy roads.

BACKGROUND ART

Heretofore, for pneumatic tires manufactured for driving on icy and snowy roads, or what are called studless tires, structures have been known in which circumferential grooves extending in a tire circumferential direction and having large groove widths (e.g., 7 mm or larger) and sipes extending in a tread width direction are formed.

Such pneumatic tires makes it possible to achieve improvement in draining rainwater, wet snow, or the like having entered gaps between the road surface and the tread surface, as well as prevention of skidding on icy and snowy roads.

PRIOR ART DOCUMENT

Patent Document

Patent Document 1: Japanese Patent Application Publication No. 2000-255217 (Pages 4 and 5, FIG. 1)

SUMMARY OF THE INVENTION

However, the conventional pneumatic tires described above have the following problem. Specifically, the formation of the circumferential grooves having large groove widths reduces the areas of land portions (blocks) constituting the tread surface, the number of sipes, and the like. Such reduction leads to the problem that although the drainage performance can be improved and skidding on icy and snowy roads can be prevented, the driving and braking performances on icy and snowy roads cannot be improved.

The present invention has been made with this problem taken into consideration and an object of the present invention is to provide a pneumatic tire whose driving and braking performances on icy and snowy roads are further improved while securing improvement in the drainage performance and prevention of skidding on icy and snowy roads

To solve the above problems, the present invention has the following aspects. At first, in the first aspect of the present invention, in a pneumatic tire (a pneumatic tire **1**A) a circumferential groove (for example, a circumferential groove **32**) extending in a tire circumferential direction is formed by land portions (land portions **20**) constituting a tread surface (a tread surface **10**) coming into contact with a road surface. A flat groove portion (a flat groove portion **60**) and an in-groove land portion (an in-groove land portion **70**) are formed in the circumferential groove. The flat groove portion being a flat surface of a groove bottom of the circumferential groove. The in-groove land portion is raised toward the tread surface side from the groove bottom of the circumferential groove. A plurality of narrow grooves (multiple narrow grooves **80**) extending in a tread width direction are formed in the in-groove land portion. A width of the circumferential groove in the tread width direction (a wide-groove width W**1**) is 5 to 30% of a width of the tread surface in the tread width direction (a tread width TW).

According to the above aspect, the flat groove portion is formed in the circumferential groove, and the wide-groove width is 5 to 30% of the tread width. According to such a structure, rainwater having entered the circumferential groove can be drained easily, whereby the drainage performance can be improved. Moreover, since snow can securely enter the circumferential groove, it is possible to prevent skidding on icy and snowy roads.

In addition, the in-groove land portion is formed in the circumferential groove, and the multiple narrow grooves extending in the tread width direction are formed in the in-groove land portion. According to such a structure, an effect of causing the narrow grooves to hook snow entering the circumferential groove (what is called edge effect) increases, whereby the driving and braking performances on icy and snowy roads can be further improved.

In another aspect, the circumferential groove is provided in plurality. the circumferential groove in which the flat groove portion and the in-groove land portion are formed has the largest width in the tread width direction among the plurality of circumferential grooves.

In the other aspect, a groove depth from the tread surface of the land portions to an upper surface portion (an upper surface portion **72**) of the in-groove land portion (first groove depth D**1**) is 60 to 95% of a depth from the tread surface of the land portions to the groove bottom of the circumferential groove (second groove depth D**2**).

In the other aspect, a width of each of the narrow grooves in the tire circumferential direction (narrow-groove width W**2**) is 1 to 8 mm.

In the other aspect, an angle formed between each of the narrow grooves and a straight line perpendicular to an equatorial plane of the tire (narrow-groove angle α) is 0 to 45 degrees.

In the other aspect, a depth from a groove bottom (a groove bottom **81**) of each of the narrow grooves to an upper surface of the in-groove land portion (narrow-groove depth D**3**) is 50 to 100% of a height from the groove bottom of the circumferential groove to the upper surface of the in-groove land portion (in-groove-land-portion height H).

In the other aspect, a clearance (a clearance **90**) is formed between the in-groove land portion and the land portion located at an opposite side of the flat groove portion.

In the other aspect, a cross section of the flat groove portion taken along a plane extending in the tread width direction and a tire radial direction is in a same shape in the tire circumferential direction, and a distance from the flat groove portion to an equatorial plane of the tire in the tread width direction is constant in the tire circumferential direction.

In the other aspect, a plurality of lug grooves extending in the tread width direction are formed at least in part of the land portions.

In the other aspect, the number of the narrow grooves formed between each pair of the adjacent lug grooves is two to eight.

In the other aspect, cutout portions (cutout portions **85**) extending respectively from the narrow grooves in the tread width direction are formed in a corresponding one of the land portions. A width of each of the cutout portions in the tire circumferential direction (a cutout width W**3**) is substantially equal to a width of each of the narrow grooves in the tire circumferential direction.

In the other aspect, a cross section of the in-groove land portion taken along a plane extending in the tread width direction and a tire radial direction is in a substantially rectangular shape.

In the other aspect, wherein a straight line (a straight line L**3**) extending along an end portion of the in-groove land portion located at the flat groove portion side is inclined with respect to an equatorial plane of the tire.

According to the present invention, it is possible to provide a pneumatic tire whose driving and braking performances on icy and snowy roads are further improved while securing improvement in drainage performance and prevention of skidding on icy and snowy roads.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a developed view showing a tread pattern of a pneumatic tire **1**A according to a first embodiment.

FIG. **2** is an enlarged view showing a part of the pneumatic tire **1**A according to the first embodiment.

FIG. **3** is a perspective view showing a part of a circumferential groove **32** according to the first embodiment.

FIG. **4** is a cross-sectional view, in the tread width direction, of the circumferential groove **32** according to the first embodiment (cross-sectional view taken along the line A-A of FIG. **3**).

FIG. **5** is a cross-sectional view, in the tire circumferential direction, of the circumferential groove **32** according to the first embodiment (cross-sectional view taken along the B-B line of FIG. **3**).

FIG. **6** is a perspective view showing a part of a circumferential groove **32** according to a modification.

FIG. **7** is a cross-sectional view, in the tread width direction, of the circumferential groove **32** according to the modification (cross-sectional view taken along the line C-C of FIG. **6**).

FIG. **8** is a developed view showing a tread pattern of a pneumatic tire **1**B according to a second embodiment.

FIG. **9** is an enlarged view showing a part of the pneumatic tire **1**B according to the second embodiment.

FIG. **10** is a perspective view showing a part of a circumferential groove **32** according to the second embodiment.

FIG. **11** is a developed view showing a tread pattern of a pneumatic tire **100** according to Comparative Example.

MODES FOR CARRYING OUT THE INVENTION

Next, some examples of the pneumatic tire according to the present invention will be described by referring to the drawings. Note that portions that are the same or similar across the drawings to be described below are denoted by the same or similar reference numerals. However, it should be also noted that the drawings are schematic and dimensional proportions may differ from the actual ones.

Accordingly, specific dimensions and the like should be determined by taking into consideration the description to be given below. Moreover, dimensional relationships and proportions may differ from one drawing to another in some parts, as a matter of course.

First Embodiment

Structure of Tread Pattern

In the following, the structure of a tread pattern of a pneumatic tire **1**A according to a first embodiment will be described by referring to the drawings. FIG. **1** is a developed view showing the tread pattern of the pneumatic tire **1**A according to the first embodiment. FIG. **2** is an enlarged view showing a part of the pneumatic tire **1**A according to the first embodiment.

The pneumatic tire **1**A according to the first embodiment is a common radial tire including bead parts, a carcass layer, and a belt layer (not illustrated). Moreover, the pneumatic tire **1**A according to the first embodiment has a pattern which is asymmetrical about the tire's equatorial plane CS.

As shown in FIGS. **1** and **2**, the pneumatic tire **1**A includes a tread surface **10** that comes into contact with the road surface, i.e., a land portion **20** that forms the surface of the tread part. By the land portion **20**, formed are: multiple circumferential grooves **30** extending in the tire circumferential direction; multiple lug grooves **40** extending in the tread width direction; and multiple sipes **50** being narrower than any of the circumferential grooves **30** and the lug grooves **40**.

The land portion **20** is provided in plurality at predetermined intervals in the tire circumferential direction and the tread width direction. These multiple land portions **20** correspond to a land portion **21**, a land portion **22**, a land portion **23**, a land portion **24**, and a land portion **25**, from the right to the left in FIG. **1**.

In the land portion **21**, there are formed: multiple lug grooves **41** dividing the land portion **21**; multiple sipes **51**A extending in the tire circumferential direction; and multiple sipes **51**B extending in the treat width direction. In the land portion **22**, there are formed multiple lug grooves **42** dividing the land portion **22**, and multiple sipes **52** extending in the tread width direction.

In the land portion **23**, there are formed multiple lug grooves **43** extending substantially parallel to the lug grooves **42**, and multiple sipes **53** extending in the tread width direction. One end portion of each lug groove **43** is opened to a circumferential groove **33** to be described later, whereas the other end portion of the lug groove **43** ends inside the land portion **23**. In other words, the land portion **23** is formed into a rib shape.

In the land portion **24**, there are formed: multiple lug grooves **44**A dividing the land portion **24**; multiple lug grooves **44**B extending substantially parallel to the lug grooves **42** and the lug grooves **43**; and multiple sipes **54** extending in the tread width direction. One end portion of each lug groove **44**B is opened to the circumferential groove **33** to be described later, whereas the other end portion of the lug groove **43** ends inside the land portion **24**. In the land portion **25**, there are formed: multiple lug grooves **45** dividing the land portion **25**; multiple sipes **55**A extending in the tire circumferential direction; and sipes **55**B extending in the tread width direction.

The multiple (four in the drawings) circumferential grooves **30** are provided at predetermined intervals in the tread width direction. In the following, these circumferential grooves **30** correspond to a circumferential groove **31**, a circumferential groove **32**, a circumferential groove **33**, and a circumferential groove **34**, from the right to the left in FIG. **1**.

Among these multiple circumferential grooves **30**, the circumferential groove **32** has the largest width in the tread width direction. The width of the circumferential groove **32** in the tread width direction (hereinafter, wide-groove width W**1**) is 5 to 30% of the width of the tread surface in the tread width direction (hereinafter, tread width TW).

(Structure of Circumferential Groove)

Next, the structure of the above-described circumferential groove **32** will be described by referring to the drawings. FIG. **3** is a perspective view showing a part of the circumferential groove **32** according to the first embodiment. In FIG. **3**, the sipes **50** are omitted. FIG. **4** is a cross-sectional view, in the tread width direction, of the circumferential groove **32** according to the first embodiment (cross-sectional view taken along the line A-A of FIG. **3**). FIG. **5** is a cross-sectional view, in the tire circumferential direction, of the circumferential groove **32** according to the first embodiment (cross-sectional view taken along the B-B line of FIG. **3**).

As shown in FIGS. **3** to **5**, the circumferential groove **32** includes therein a flat groove portion **60** and an in-groove land portion **70**. The flat groove portion **60** is a flat surface of a groove bottom **32***a* of the circumferential groove **32**, whereas the in-groove land portion **70** is a portion raised toward the tread surface **10** side from the groove bottom **32***a* of the circumferential groove **32**.

The flat groove portion **60** is provided closer to the tire equatorial plane CS side than the in-groove land portion **70**. The cross section of the flat groove portion **60** taken along a plane extending in the tread width direction and a tire radial direction is in a same shape in the tire circumferential direction (see FIG. **4**). In addition, a distance D from the flat groove portion **60** to the tire equatorial plane CS in the tread width direction is constant the same in the tire circumferential direction (see FIG. **1**).

The in-groove land portion **70** is formed to be continuous with the land portion **22** in the tread width direction. The cross section of the in-groove land portion **70** taken along a plane extending in the tread width direction and the tire radial direction is in a substantially rectangular shape (see FIG. **4**). Specifically, in the cross section, an upper surface portion **72** of the in-groove land portion **70** extends in the tread width direction. Moreover, in the cross section, from an inner edge **71** (end portion) of the in-groove land portion **70** located at the flat groove portion **60** side, a groove wall **73** extends toward the flat groove portion **60** (the groove bottom **32***a* of the circumferential groove **32**) in the tire radial direction.

A straight line L**1** extending along the inner edge **71** of the in-groove land portion **70** located at the flat groove portion **60** side is substantially parallel to the tire equatorial plane CS (see FIG. **3**). In other words, the straight line L**1** extends in the tire circumferential direction.

A groove depth from the tread surface **10** of the land portion **22** to the upper surface portion **72** of the in-groove land portion **70** (hereinafter, first groove depth D**1**) is set to be 60 to 95% of a groove depth from the tread surface of the land portion **23** to the groove bottom **32***a* of the circumferential groove **32** (hereinafter, second groove depth D**2**) (see FIG. **4**).

In the in-groove land portion **70**, there are formed the lug grooves **42** continuous from the land portion **22**, and multiple narrow grooves **80** extending in the tread width direction. The angle that each narrow groove **80** forms with respect to a straight line L**2** perpendicular to the tire equatorial plane CS (hereinafter, narrow-groove angle α) is 0 to 45 degrees (see FIG. **1**).

The number of narrow grooves **80** formed between the adjacent two lug grooves **42** is two to eight (three in the drawings). The width of each narrow groove **80** in the tire circumferential direction (hereinafter, narrow-groove width W**2**) is 1 to 8 mm (see FIG. **5**).

A depth from a groove bottom **81** of each narrow groove **80** to the upper surface portion **72** of the in-groove land portion **70** (hereinafter, narrow-groove depth D**3**) is 50 to 100% of a height from the groove bottom **32***a* of the circumferential groove **32** to the upper surface portion **72** of the in-groove land portion **70** (hereinafter, in-groove-land-portion height H) (see FIG. **5**).

Meanwhile, in the land portion **22**, cutout portions **85** are formed which extend in the tread width direction from the respective narrow grooves **80** and end inside the land portion **22**. The width of each cutout portion **85** in the tire circumferential direction (hereinafter, cutout width W**3**) is substantially equal to the narrow-groove width W**2**.

(Operation and Effect)

In the first embodiment, the flat groove portion **60** is formed in the circumferential groove **32**, and the wide-groove width W**1** is 5 to 30% of the tread width TW. According to such a structure, rainwater having entered the circumferential groove **32** can be drained easily, whereby the drainage performance can be improved. Moreover, since snow can securely enter the circumferential groove **32**, it is possible to prevent skidding on icy and snowy roads.

If the wide-groove width W**1** is smaller than 5% of the tread width TW, the amount of rainwater entering the circumferential groove **32** becomes so small that improvement in the drainage performance cannot be expected. Meanwhile, if the wide-groove width W**1** is larger than 30% of the tread width TW, the contact area of the tread surface **10** with the road surface becomes so small that skidding on icy and snow roads cannot be prevented and the driving and braking performances cannot be improved.

In addition, the in-groove land portion **70** is formed in the circumferential groove **32**, and the multiple narrow grooves **80** extending in the tread width direction are formed in the in-groove land portion **70**. According to such a structure, an effect of causing the narrow grooves **80** to hook snow entering the circumferential groove **32** (what is called edge effect) increases, whereby the driving and braking performances on icy and snowy roads can be further improved.

In the first embodiment, among the multiple circumferential grooves, the circumferential groove **32** has the largest width as it has the wide-groove width W**1**. Moreover, the cross section of the flat groove portion **60** taken along a plane extending in the tread width direction and the tire radial direction is in a same shape in the tire circumferential direction. Furthermore, the distance D from the flat groove portion **60** to the tire equatorial plane CS in the tread width direction is constant in the tire circumferential direction. According to such a structure, rainwater having entered the circumferential groove **32** can be drained easily, whereby reduction in the drainage performance can be prevented.

In the first embodiment, the narrow-groove width W**2** is 1 to 8 mm. By setting the narrow-groove width W**2** to 1 mm or larger, the effect of causing the narrow grooves **80** to hook snow entering the circumferential groove **32** (what is called edge effect) increases, whereby the driving and braking performances on icy and snowy roads can be further improved. Meanwhile, by setting the narrow-groove width W**2** to 8 mm or smaller, the resistance of rainwater or the like entering the circumferential groove **32** does not increase severely, whereby reduction in the drainage performance can be prevented.

In the first embodiment, the first groove depth D**1** is 60 to 95% of the second groove depth D**2**. By setting the first groove depth D**1** to 60% of the second groove depth D**2** or larger, the volume of the circumferential groove **32** does not decrease excessively, whereby reduction in the drainage performance can be prevented. Meanwhile, by setting the first groove depth D**1** to 95% of the second groove depth D**2** or smaller, the effect of causing the narrow grooves **80** to hook snow entering the circumferential groove **32** (what is called edge effect) can be secured, whereby the driving and braking performances on icy and snowy roads can be further improved.

In the first embodiment, the narrow-groove angle α is 0 to 45 degrees. By setting the narrow-groove angle α to 45 degrees or smaller, the effect of causing the in-groove land portion **70** and the narrow grooves **80** to hook snow entering the circumferential groove **32** (what is called edge effect) increases, whereby the driving and braking performances on icy and snowy roads can be further improved.

In the first embodiment, the narrow-groove depth D3 is 50 to 100% of the in-groove-land-portion height H. By setting the narrow-groove depth D3 to 50% of the in-groove-land-portion height H or larger, the effect of causing the narrow grooves **80** to hook snow entering the circumferential groove **32** (what is called edge effect) can be secured, whereby the driving and braking performances on icy and snowy roads can be further improved. Meanwhile, by setting the narrow-groove depth D3 to 100% of the in-groove-land-portion height H or smaller, the effect of causing the narrow grooves **80** to hook snow entering the circumferential groove **32** (what is called edge effect) can be secured without decrease in rigidity of the in-groove land portion **70**, whereby the driving and braking performances on icy and snowy roads can be further improved.

In the first embodiment, the multiple lug grooves **40** are formed at least in part of the land portions **20**. According to such a structure, the driving and braking performances on dry roads are improved, in addition to those on icy and snowy roads.

In the first embodiment, the number of narrow grooves **80** formed between the adjacent two lug grooves **42** is two to eight. By providing two or more narrow grooves **80** between the adjacent two lug grooves **42**, the effect of causing the narrow grooves **80** to hook snow entering the circumferential groove **32** (what is called edge effect) increases, whereby the driving and braking performances on icy and snowy roads can be further improved. Meanwhile, by providing eight or fewer narrow grooves **80** between the adjacent two lug grooves **42**, the resistance of rainwater, snow, or the like entering the circumferential groove **32** does not increase severely, whereby reduction in the drainage performance can be prevented.

In the first embodiment, the cutout portions **85** are formed in the land portion **22** at such positions as to face their respective narrow grooves **80**. The cutout width W3 is substantially equal to the narrow-groove width W2. According to such a structure, the effect of causing the narrow grooves **80** to hook snow entering the circumferential groove **32** (what is called edge effect) increases, whereby the driving and braking performances on icy and snowy roads can be further improved.

In the first embodiment, in the land portion **23** located at the tire equatorial plane CS side of the circumferential groove **32** where the flat groove portion **60** and the in-groove land portion **70** are formed, one end portion of each lug groove **43** is opened to the circumferential groove **32** whereas the other end portion of the lug groove **43** ends inside the land portion **23**. According to such a structure, the resistance of rainwater, snow, or the like entering the circumferential groove **32** does not increase severely, whereby reduction in the drainage performance can be prevented.

(Modification)

The in-groove land portion **70** according to the above first embodiment is described as one formed to be continuous with the land portion **22** in the tread width direction, but may be modified in the following manner. Note that the same portions as those of the pneumatic tire **1**A according to the above first embodiment will be denoted by the same reference numerals, and differences therebetween will be mainly described.

FIG. **6** is a perspective view showing a part of the circumferential groove **32** according to the modification. FIG. **7** is a cross-sectional view, in the tread width direction, of the circumferential groove **32** according to the modification (cross-sectional view taken along the line C-C of FIG. **6**).

As shown in FIGS. **6** and **7**, in the land portion **22** with the in-groove land portion **70** given right next thereto, the cutout portions **85** are formed at such positions as to face their respective narrow grooves **80**. A clearance **90** is formed between the in-groove land portion **70** and the land portion **22** given right next to the in-groove land portion **70**.

In this modification, the clearance **90** is formed between the in-groove land portion **70** and the land portion **22** given adjacent to the in-groove land portion **70**. According to such a configuration, the clearance **90** can be secured in the circumferential groove **32** in addition to the flat groove portion **60**. Hence, the drainage performance can be further improved.

Second Embodiment

In the following, the structure of a tread pattern of a pneumatic tire **1**B according to a second embodiment will be described by referring to FIGS. **8** to **10**. FIG. **8** is a developed view showing the tread pattern of the pneumatic tire **1**B according to the second embodiment. FIG. **9** is an enlarged view showing a part of the pneumatic tire **1**B according to the second embodiment. In FIG. **9**, the sipes **50** are omitted. FIG. **10** is a perspective view showing a part of a circumferential groove **32** according to the second embodiment. Note that the same portions as those of the pneumatic tire **1**A according to the above first embodiment will be denoted by the same reference numerals, and differences therebetween will be mainly described.

As shown in FIGS. **8** and **9**, in a land portion **22** located at the tread shoulder side of the circumferential groove **32**, one end portion of each lug groove **42** is opened to the circumferential groove **31** whereas the other end portion of the lug groove **42** ends inside the land portion **22**. In other words, the land portion **22** is formed into a rib shape.

In the land portion **23** located at the tire equatorial plane CS side of the circumferential groove **32**, the lug grooves **43** divide the land portion **23**.

As shown in FIG. **10**, a straight line L3, which extends parallel to the inner edges **71** of the in-groove land portion **70** located at the flat groove **60** side, is inclined with respect to the tire equatorial plane CS. In other words, the inner edges **71** are formed into a zigzag shape with respect to the tire circumferential direction.

(Operation and Effect)

In the second embodiment, the straight line L3, which extends parallel to the inner edges **71** of the in-groove land portion **70** located at the flat groove **60** side, is inclined with respect to the tire equatorial plane CS. According to such a structure, an effect of causing the narrow grooves **80** to hook snow entering the circumferential groove **32** (what is called edge effect) increases, whereby the driving and braking performances on icy and snowy roads can be further improved.

(Comparative Evaluation)

Next, to further clarify the effects of the present invention, description will be given of a comparative evaluation carried out by using a pneumatic tire according to Comparative Example and the pneumatic tires according to Examples 1 and 2. Note that the present invention is not to be limited by these examples.

Data on each pneumatic tire was measured under the conditions listed below.

Tire size: 205/55R16

Wheel size: 6.5 J×16

Internal pressure condition: regular internal pressure

By referring to Table 1, description will be given of tread pattern structure, steering performance on snow roads, braking performance on snow roads, driving performance on snow roads, performance on wet-snow roads, and performance against hydroplaning on rainy roads, of each pneumatic tire.

TABLE 1

	Comparative Example	Example 1	Example 2
Negative ratio of tread surface	30.3%	30.3%	30.3%
Wide-groove width W1	18 mm (9% of TW)	18 mm (9% of TW)	18 mm (9% of TW)
Narrow-groove angle α	—	15 degrees	15 degrees
Number of narrow grooves	—	3 (grooves/pitch)	3 (grooves/pitch)
Narrow-groove width W4 (Lug groove between narrow grooves)	—	2 mm (2.8 mm)	2 mm
Flat-groove width W2	—	5 mm	7 mm
Steering performance on snow road	100	107	106
Braking performance on snow roads	100	107	106
Driving performance on snow roads	100	108	107
Performance on wet-snow roads	100	107	108
Performance against hydroplaning on rainy roads	100	101	103

* Negative ratio of tread surface = the ratio of grooves to tread surface (ground contact surface).

Now, the pneumatic tires according to Comparative Example and Examples 1 and 2 are described briefly. Note that these pneumatic tires have the same structures, except for the structures of the flat groove portion **60** and in-groove land portion **70** formed in the circumferential groove **32** and of the land portions **22** and **23** adjacent to the circumferential groove, which are to be described below.

In the pneumatic tire **100** according to Comparative Example, the flat groove portion **60** and the in-groove land portion **70** are not formed in the circumferential groove **32**. The land portion **23** located at the tire equatorial plane CS side of the circumferential groove **32** is formed into a rib shape (see FIG. **11**).

In the pneumatic tire **1**A according to Example 1, the flat groove portion **60** and the in-groove land portion **70** (narrow grooves **80**) are formed in the circumferential groove **32**, as described in the first embodiment. The straight line L**1** extending along the inner edge **71** of the in-groove land portion **70** located at the flat groove portion **60** side is substantially parallel to the tire equatorial plane CS. The land portion **23** located at the tire equatorial plane CS side of the circumferential groove **32** is formed into a rib shape (see FIGS. **1** to **5**).

In the pneumatic tire **1**B according to the second embodiment, the flat groove portion **60** and the in-groove land portion **70** (narrow grooves **80**) are formed in the circumferential groove **32**, as described in the second embodiment. The straight line L**3** extending parallel to the inner edges **71** of the in-groove land portion **70** located at the flat groove portion **60** side are inclined with respect to the tire equatorial plane CS. The land portion **22** located at the tread shoulder side of the circumferential groove **32** is formed into a rib shape (see FIGS. **8** to **10**).

<Steering Performance on Snow Road>

The steering performance (total performance including the straight line stability, cornering performance, lane change performance, and the like) on snow roads was evaluated by driving vehicles equipped with the pneumatic tires on a snowy-road course. Note that in Table 1, the steering performance of each of the vehicles equipped with the pneumatic tires **1**A and **1**B according to Examples 1 and 2 is shown in the form of an index value that uses, as reference (**100**), the steering performance of the vehicle equipped with the pneumatic tire **100** according to Comparative Example. A larger index value means a better steering performance on the snow road.

The result shows that the vehicles equipped with the pneumatic tires **1**A and **1**B according to Examples 1 and 2 are superior to the vehicle equipped with the pneumatic tire **100** according to Comparative Example in terms of the steering performance on the snow road. In other words, the result shows that a pneumatic tire with the flat groove portion **60** and the in-groove land portion **70** formed in the circumferential groove **32** and the narrow grooves **80** formed in the in-groove land portion **70** can improve the steering performance on snow roads.

<Braking Performance on Snow Road>

The braking performance on snow roads was evaluated as follows. On a snowy-road course, vehicles equipped with the pneumatic tires were driven at a speed of 40 km/h, and the distances (braking distance) required for sudden stop of the vehicles in driving were measured. Note that in Table 1, the braking distance of each of the vehicles equipped with the pneumatic tires **1**A and **1**B according to Examples 1 and 2 is shown in the form of an index value that uses, as reference (**100**), the braking distance of the vehicle equipped with the pneumatic tire **100** according to Comparative Example. A larger index value means a better braking performance on the snow road.

The result shows that the vehicles equipped with the pneumatic tires **1**A and **1**B according to Examples 1 and 2 are superior to the vehicle equipped with the pneumatic tire **100** according to Comparative Example in terms of the braking performance on the snow road. In other words, the result shows that a pneumatic tire with the flat groove portion **60** and the in-groove land portion **70** formed in the circumferential groove **32** and the narrow grooves **80** formed in the in-groove land portion **70** can improve the braking performance on snow roads.

<Driving Performance on Snow Road>

The driving performance on snow roads was evaluated as follows. On a snowy-road course, vehicles equipped with the pneumatic tires were accelerated from a stopped state and driven a distance of 50 m, and the acceleration times of the vehicles were measured. Note that in Table 1, the acceleration time of each of the vehicles equipped with the pneumatic tires **1**A and **1**B according to Examples 1 and 2 is shown in the form of an index value that uses, as reference (**100**), the acceleration time of the vehicle equipped with the pneumatic tire **100** according to Comparative Example. A larger index value means a better steering performance on the snow road.

The result shows that the vehicles equipped with the pneumatic tires **1**A and **1**B according to Examples 1 and 2 are superior to the vehicle equipped with the pneumatic tire **100** according to Comparative Example in terms of the driving performance on the snow road. In other words, the result shows that a pneumatic tire with the flat groove portion **60** and the in-groove land portion **70** formed in the circumferential groove **32** and the narrow grooves **80** formed in the in-groove land portion **70** can improve the driving performance on snow roads.

<Performance on Wet-Snow Road>

The performance on wet-snow roads was evaluated as follows. On a course with wet snow having a liquid-water content of 80 to 90% (including slushy snow) under a temperature condition of 0±1 C.°, the vehicles equipped with the pneumatic tires were caused to accelerate, and then critical speeds at which the pneumatic tires mounted on the vehicles stopped making contact with the road surface were measured. Note that in Table 1, the critical speed of each of the vehicles equipped with the pneumatic tires **1**A and **1**B according to Examples 1 and 2 is shown in the form of an index value that uses, as reference (**100**), the critical speed of the vehicle equipped with the pneumatic tire **100** according to Comparative Example. A larger index value means a better performance on wet-snow roads road.

The result shows that the vehicles equipped with the pneumatic tires **1**A and **1**B according to Examples 1 and 2 are superior to the vehicle equipped with the pneumatic tire **100** according to Comparative Example in terms of the performance on wet-snow roads. In other words, the result shows that a pneumatic tire with the flat groove portion **60** and the in-groove land portion **70** formed in the circumferential groove **32** and the narrow grooves **80** formed in the in-groove land portion **70** can improve the performance on wet-snow roads.

<Performance against Hydroplaning on Rainy Roads>

The performance against hydroplaning on rainy roads was evaluated as follows. On a rainy road course having a water depth of 5 mm, the vehicles equipped with the pneumatic tires were driven, and then critical speeds at which hydroplaning occurred in which the pneumatic tires floated over the road surface and skidding occurred were measured. Note that in Table 1, the critical speed of each of the vehicles equipped with the pneumatic tires **1**A and **1**B according to Examples 1 and 2 is shown in the form of an index value that uses, as reference (**100**), the critical speed of the vehicle equipped with the pneumatic tire **100** according to Comparative Example. A larger index value means a better performance against hydroplaning on rainy roads.

The result shows that the vehicles equipped with the pneumatic tires **1**A and **1**B according to Examples 1 and 2 are superior to the vehicle equipped with the pneumatic tire **100** according to Comparative Example in terms of the performance against hydroplaning on rainy roads. In other words, the result shows that a pneumatic tire with the flat groove portion **60** and the in-groove land portion **70** formed in the circumferential groove **32** and the narrow grooves **80** formed in the in-groove land portion **70** can improve the performance against hydroplaning on rainy roads.

Other Embodiments

As described above, the details of the present invention have been disclosed by using the embodiments of the present invention. However, it should not be understood that the description and drawings which constitute part of this disclosure limit the present invention.

In the above embodiments, the flat groove portion **60** and the in-groove land portion **70** are described as ones formed in the circumferential groove **32** which has the largest width in the tread width direction among the multiple circumferential grooves **30**, but are not limited to those. The flat groove portion **60** and the in-groove land portion **70** may be formed in one or more of the other circumferential grooves **30**, as a matter of course.

In the above embodiments, the flat groove portion **60** is described as one provided closer to the tire equatorial plane CS than the in-groove land portion **70** and, but is not limited to this. The flat groove portion **60** may be provided, for example, on the opposite side, i.e., provided closer to the tread shoulder portion side than the in-groove land portion **70**, as a matter of course.

In the above embodiments, the cross section of the in-groove land portion **70** taken along a plane extending in the tread width direction and the tire radial direction is described as being in a substantially rectangular shape, but is not limited to this. The cross section may be in a substantially triangular or trapezoidal shape, as a matter of course.

In the above embodiment, the pneumatic tire **1**A is described as a common radial tire including bead parts, a carcass layer, and a belt layer (not illustrated), but is not limited to this. The pneumatic tire **1**A may be a tire other than radial tire (e.g., bias tire), or a tubed tire.

From this disclosure, various alternative embodiments, examples, and operation techniques will be easily found by those skilled in the art. Accordingly, the technical scope of the present invention should be determined only by the matters to define the invention in the scope of claims regarded as appropriate based on the description.

Note that the entire content of Japanese Patent Application No. 2008-174656 (filed on Jul. 3, 2008) is incorporated herein by reference.

INDUSTRIAL APPLICABILITY

As described hereinabove, the pneumatic tire according to the present invention is a pneumatic tire whose driving and braking performances on icy and snowy roads are further improved while securing improvement in the drainage performance and prevention of skidding on icy and snowy roads, and is therefore useful for tire manufacturing techniques and the like.

The invention claimed is:

1. A pneumatic tire in which a circumferential groove extending in a tire circumferential direction is formed by land portions constituting a tread surface coming into contact with a road surface, wherein

a flat groove portion and an in-groove land portion are formed in the circumferential groove, the flat groove portion being a flat surface of a groove bottom of the circumferential groove, the in-groove land portion being raised toward the tread surface side from the groove bottom of the circumferential groove,

a plurality of narrow grooves extending in a tread width direction are formed in the in-groove land portion,

cutout portions extending respectively from the plurality of narrow grooves in the tread width direction are formed in a corresponding one of the land portions and ending inside the land portion, wherein a width of each of the cutout portions in the tire circumferential direction is substantially equal to a width of each of the narrow grooves in the tire circumferential direction, and

a width of the circumferential groove in the tread width direction is 5 to 30% of a width of the tread surface in the tread width direction, wherein a depth from a groove bottom of each of the narrow grooves to an upper surface of the in-groove land portion is 50 to 100% of a height from the groove bottom of the circumferential groove to the upper surface of the in-groove land portion.

2. The pneumatic tire according to claim 1, wherein

the circumferential groove is provided in plurality, and

the circumferential groove in which the flat groove portion and the in-groove land portion are formed has the largest width in the tread width direction among the plurality of circumferential grooves.

3. The pneumatic tire according to claim 1, wherein a groove depth from the tread surface of the land portions to an upper surface portion of the in-groove land portion is 60 to 95% of a depth from the tread surface of the land portions to the groove bottom of the circumferential groove.

4. The pneumatic tire according to claim 1, wherein a width of each of the narrow grooves in the tire circumferential direction is 1 to 8 mm.

5. The pneumatic tire according to claim 1, wherein an angle formed between each of the narrow grooves and a straight line perpendicular to an equatorial plane of the tire is 0 to 45 degrees.

6. The pneumatic tire according to claim 1, wherein a clearance is formed between the in-groove land portion and the land portion located at an opposite side of the flat groove portion.

7. The pneumatic tire according to claim 1, wherein

a cross section of the flat groove portion taken along a plane extending in the tread width direction and a tire radial direction is in a same shape in the tire circumferential direction, and

a distance from the flat groove portion to an equatorial plane of the tire in the tread width direction is constant in the tire circumferential direction.

8. The pneumatic tire according to claim 1, wherein

a plurality of lug grooves extending in the tread width direction are formed at least in part of the land portions, and

a lug groove of the plurality of lug grooves has one end portion opened to the circumferential groove and continuous from the land portion to the in-groove land portion.

9. The pneumatic tire according to claim 8, wherein the number of the narrow grooves formed between each pair of the adjacent lug grooves is two to eight.

10. The pneumatic tire according to claim 1, wherein a cross section of the in-groove land portion taken along a plane extending in the tread width direction and a tire radial direction is in a substantially rectangular shape.

11. The pneumatic tire according to claim 1, wherein a straight line extending along an end portion of the in-groove land portion located at the flat groove portion side is inclined with respect to an equatorial plane of the tire.

* * * * *